PATENT SPECIFICATION

701,557

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COMPLETE SPECIFICATION

Improvements relating to Gas Turbine Power Plant

We, CENTRAX POWER UNITS LIMITED, a British Company of 87, High Street, Brentford, Middlesex, and RICHARD HENRY HOWARD BARR, a British Subject of the Company's address, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to gas turbine plant.

A main object of the invention is the provision of gas turbine plant having a good part-load performance, more particularly plant of an order of power suitable for the propulsion of road vehicles or small marine craft.

The prime movers of road vehicles usually operate at or near full load conditions for short periods only, and run most of the time at low or medium loads, and so a gas turbine power plant for road vehicle propulsion having poor part-load performance (which involves relatively high fuel consumption at low loads) is not an economical proposition for normal use.

To obtain improved part-load performance in gas turbine engines, it is desirable for the pressure ratio of the compressor and the maximum cycle temperature to be kept as high as possible when the power output is reduced. A substantial improvement in this sense can be achieved if. when the supply of fuel for combustion is reduced, an appropriate reduction (for any given rotational speed of the compressor) is made in the quantity of working fluid taking part in the cycle (which quantity is usually known as the "mass flow"), for example by the use of variable-admission nozzle means to vary the admission of working fluid to the turbine or turbines. This method of control necessitates the use of a compressor which is capable of functioning stably (i.e. in a surge-free manner) and with an acceptable pressure ratio over a wide range of mass flow variation at any given rotational speed up to the maximum.

To explain the nature of the problem more clearly reference will be made to Figure 1 of the accompanying drawings which shows the pressure ratio/mass flow characteristics of a centrifugal compressor of a kind in common use for gas turbine plant, i.e. a compressor of which the impeller discharges into diffuser passages of fixed throat area.

In Figure 1 pressure ratio (Pr) is plotted against mass flow (Mf) for a series of rotational speeds N_1—N_6, N_1 being full speed. The characteristics shown are relatively "humped" in shape, each having a point of maximum pressure ratio (such as m for speed N_4) on each side of which the characteristics fall with increase or decrease of mass flow. At the higher speeds the point of maximum pressure is theoretical, since it falls on the left of the surge line. The downward slope on the left of the point m is known as the positive slope, that on the right as the negative slope. As is well known in the art, the region of positive slope is inherently unstable, and continued reduction of Mf for a given speed results in the unstable flow known as surging. The points on each characteristic at which surging is liable to commence are connected by the line S—S (the surge line). Taking the mass flow range between the compressor operating line (the line connecting the design points D) and the surge line as representing the range of mass flow over which the compressor will give stable operation at a satisfactory pressure ratio, it will be seen that this range is relatively small, especially at the higher speeds and pressure ratios. Such a compressor would be entirely unsuitable for a plant employing the method of control referred to above.

It has been proposed, however to provide centrifugal compressors with diffuser ducting of variable cross-sectional area at the throat and to adjust this area, and the angle of the vanes defining said ducting, in conformity with variations in the mass flow passing through the compressor. Thus, if Figure 1 represents the position of the surge line when the diffuser area is at a maximum, the reduction of the diffuser area has the effect of shifting the surge line to the left, and hence increases the range of surge-free operation.

[*Price* 2/8]

The present invention, according to one aspect, provides a gas turbine plant for the production of shaft power, comprising a centrifugal compressor having diffuser ducting comprising passages of variable throat area, combustion apparatus, a turbine system to drive the compressor and supply external shaft power, said system including at least one inward radial-flow turbine in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area, mechanism to vary the mass flow of the working fluid by modifying the turbine throat area and to effect conforming adjustment in the diffuser throat area, and fuel-control means to vary the quantity of fuel burnt in the combustion apparatus, the operation of the said mechanism and of the fuel-control means being so interdependent that a variation in mass flow effected by adjustment of the turbine nozzle area is associated with a corresponding variation in the quantity of fuel burnt.

The turbine system may consist of a turbine which drives the compressor and also supplies external shaft power.

Alternatively the turbine system may consist of a turbine to drive the compressor, and a mechanically independent turbine to supply external shaft power; these turbines may be supplied with working fluid in series. Each turbine may be of the inward radial-flow type in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area.

The, or each, variable nozzle means may consist of a ring of vanes angularly adjustable in unison to vary the throat area of the nozzle passages they define.

According to another aspect the invention provides a gas turbine for the production of shaft power, comprising a centrifugal compressor having diffuser ducting comprising passages of variable throat area, heat input means, and a single turbine which drives the compressor and also supplies external shaft power, said turbine being of the inward radial-flow type in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area.

According to a further aspect the invention provides a gas turbine plant for the production of shaft power, comprising a centrifugal compressor having diffuser ducting comprising passages of variable throat area, heat input means, a turbine to drive the compressor, and a mechanically independent turbine to supply external shaft power, said turbines being fed with working fluid in series (either turbine being in the high pressure position) and each turbine being of the inward radial-flow type in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area.

According to yet another aspect the invention provides a gas turbine plant for the production of shaft power, comprising a centrifugal compressor having diffuser ducting comprising passages of variable throat area, heat input means, a turbine to drive the compressor, and a mechanically independent turbine to supply external shaft power, said turbines being fed with working fluid in series and one turbine being an inward radial-flow turbine in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area.

The expression "inward radial flow turbine" is herein used to include cases where the generally centripetal direction of the fluid through the passages defined by the rotor vanes is made up of a radial component and a substantial axial component (e.g. the case of so-called "mixed flow" or "diagonal flow" turbines).

For the sake of example one form of power plant according to the invention will now be described with reference to the accompanying drawings in which:—

Figure 2 is a view of the engine from one side.

Figure 3 is a front view (i.e. from the left of Figure 2).

Figure 4 is a view on the other side.

Figure 5 is a section on the line V—V of Figure 2.

Figure 6 is similar to Fig. 4, but is partly in section.

Figure 7 is a section on the line VII—VII of Figure 3.

Figure 8 is an enlarged fragmentary sectional view of the compressor-driving turbine B, similar to the section as seen in Figure 5, but showing the mechanism for varying the angles of the nozzle vanes.

Figure 9 is a diagrammatic view of the nozzle vanes (and associated mechanism) of the turbine shown in Figure 8, looking in the direction of the arrow XI in Figure 8.

Figure 10 shows the compressor with variable diffuser vanes.

Figure 11 shows the control connections of the engine.

Figure 12 is a diagrammatic view showing an alternative, and simpler means for throttling the turbine nozzle.

The engine is of a design suitable for road vehicle propulsion, and in general arrangement comprises a centrifugal compressor A driven by a turbine B on a common shaft therewith, and an independently rotatable power turbine C mounted on a shaft at right angles to, and non-intersecting with, the common shaft of the compressor and its driving turbine. The compressed working fluid is preheated in a heat exchanger D utilising

the engine exhaust gases, and further heated by burning fuel in a single combustion chamber E located, as respects the flow of working fluid, between the heat exchanger and the compressor driving turbine. The engine may be supported in any one of various positions, but one disposition which would be convenient for a road vehicle chassis is with the said common shaft extending vertically and the shaft of the power turbine extending horizontally, say longitudinally of the chassis.

The engine illustrated is in accordance with Applicant's co-pending Applications No. 8252/49 and 25154/51 (Serial No. 700,552) and comprises a centrifugal compressor with a vaneless diffuser space. The general layout of the engine will be described in terms of this type, and the modification arising from the present invention will then be indicated.

Referring to the Figures 2—7, the impeller 1 of the single sided centrifugal compressor A takes in air through a central "eye" 2 and delivers into a vaneless annular space 3 of such size that substantially the whole of the required diffusion is obtained. From the space 3 the compressed air is discharged into a volute 4 to which is connected a duct 5 leading to the heat exchanger D where the compressed air takes up heat from the turbine exhaust gases. The compressed air leaves the heat exchanger by way of the outlet 6 and passes to the combustion system comprising a single combustion chamber E to which fuel is supplied by the inlet pipe 7 and burnt in the chamber. The fuel system is assumed to be of the well known "spill" type, and reference 8 denotes the spill line. 9 is an igniter for initiating combustion in the chamber D.

From the combustion chamber the heated compressed gases are led by way of a duct 10 to a volute 11 giving access to the variable-admission nozzle ring of the compressor-driving turbine B which is of the radial vaned centripetal flow type. The nozzle ring comprises a series of vanes 12 which are capable of simultaneous pivotal adjustment as explained below. The rotor 15 of the turbine B comprises radial vanes 16, from which the working fluid is discharged through a central eye 17. The rotor 15 is borne upon a shaft 18 which also mounts the compressor impeller 1.

From the eye 17 the gases discharged from the turbine B are led straight into a volute 19 giving access to the nozzle ring of the power turbine C which is of similar construction to the turbine B; i.e. it is of the centripetal flow type with a variable admission nozzle ring consisting of pivotable vanes 20, which direct the gases on to the radial vanes 21 of a rotor 22 mounted on a shaft 23. From the rotor 22 the gases are discharged through an axial outlet 24 to the heat exchanger D, whence they are exhausted via a duct 25. The disposition of the shaft 23 at right angles to, but non-intersecting with, the shaft 18, has the convenience that the duct leading to the volute 19 can be short and almost straight. This arrangement of the turbine shafts forms the subject of applicant's co-pending application No. 25154/51 (Serial No. 700,552). From the shaft 23 the drive is taken off through a train of reduction gears 26 contained within casings 27, 28.

The adjustment of the nozzle vanes of the turbine B is brought about as follows (Figures 8—9). The vanes 12 are mounted on stub pins 13 carrying short levers 14 the free ends of which have pins 14*a* engaging radial slots 29 in an annulus 30 supported for rotation on rollers 31. The annulus 30 has internal teeth at 32 engaged by a pinion 33 mounted on a short shaft 34 which also carries a lever 35. By the angular movement of the lever 35 the pinion 33 and annulus 30 are rotated, thus simultaneously adjusting the angle of vanes 12 and the throat area of the nozzle passages they define.

The nozzle vanes 20 of the power turbine C are adjusted by exactly similar mechanism to that of the nozzle vanes 12 of turbine B.

Up to the present the engine described is according to Applicants' co-pending Application No. 8252/49 (Serial No. 700,503). The present invention involves the substitution for the vaneless-diffuser compressor of a centrifugal compressor (of substantially known type) in which the impeller discharges into diffuser passages formed by vanes, the latter being angularly adjustable to vary the throat area of the passages they define. Figure 10 illustrates this compressor, which is basically similar in structure to the inward radial-flow turbine already described, except insofar as the difference in function necessitates alterations in design. The impeller of the compressor discharges in normal manner into diffuser passages provided by a ring of vanes 50. These, however, are each mounted on pins 13*a* carrying levers 14*b* the free ends of which have pins 14*c* engaging radial slots 29*a* in an annulus 30*a* supported for rotation on rollers 31*a*. The annulus 30 has internal teeth at 32*a* engaged by a pinion 54 mounted on a short shaft 34 which also carries a lever 53. By the angular movement of the lever 53 the pinion 54 and annulus 30*a* are rotated slightly, thus simultaneously adjusting the angle of the diffuser vanes 50 and the throat area of the nozzle passages they define. Thus the vanes 50 are adjusted by mechanism substantially the same as that which adjusts the nozzle vanes of the turbines. From the diffuser passages the fluid passes into a volute such as 4 (Figure 5).

Figure 11 shows diagrammatically the control connections of the engine. A single accelerator pedal 36 is linked to a shaft 37 which, through bevel gears 38, rotates a shaft 39 carrying lever arms 40, 41, 42, linked respectively to rods 43, 44, 45. The rod 43 operates a throttle valve 46, located in the spill

line 8, so as to vary the amount of fuel "spilled" back to the tank, and hence vary the quantity of fuel actually burnt. The rod 44 is linked to the lever 35 operating the nozzle vane adjustment of the turbine B. The rod 45 operates a movable member 47 provided with a cam-slot 48 in which rides the end of a lever 49 which adjusts the nozzle vanes of the power turbine C and corresponds in function to the lever 35.

Operation of the pedal 36 alters the quantity of fuel supplied for combustion and at the same time, by modifying the turbine nozzle throat area, acts to bring about a corresponding variation in the mass flow of working fluid through both turbines i.e. increase of mass flow (opening the nozzle vanes) is associated with an increase in the quantity of fuel burnt, and *vice versa.*

The arm 53, as shown in Figures 10 and 11, is connected to a rod 52 which is linked to the shaft 39 by a lever 51, so that when the turbine nozzle vanes are adjusted a conforming adjustment is made in the diffuser throat area, i.e. reduction in turbine nozzle area is associated with reduction in diffuser throat area, and *vice versa.*

The speed range of the compressor is relatively small, which has the further advantage that if the pedal 36 is fully depressed the plant will give full power more quickly than in an engine controlled only by fuel supply variation, in which, at low power, the compressor speed is low, and when full power is required it takes an appreciable time to "motor up" the compressor.

Moreover, less effort is required to turn over the engine for starting, because the mass flow is small at low-power settings of the pedal 36.

Figure 12 shows a simpler means of varying the nozzle throat area of the turbines B or C, or both, which involves the constructional advantage of dispensing with a ring of adjustable nozzle vanes and the associated mechanism. In Figure 12, the supply of working fluid to the turbine volute 11 is throttled by a single vane or flap 54 pivoted on a stub pin 55. In this construction the velocity and direction of the gas flow to the turbine rotor is controlled only by the dimensions and configuration of the volute 11, the quantity being controlled by adjusting the flap 54 which is moved by appropriate linkage connected to the shaft 39 (Figure 11).

Instead of providing variable nozzle means for both turbines, it may as an alternative only be provided for one turbine (i.e. either for the compressor-driving turbine or the other turbine). The invention is thought to have some useful application to plant having only one turbine, which drives the compressor and also provides the external shaft power, and in such a case there will necessarily be only one variable nozzle means.

It will be appreciated that the present invention, in addition to being well adapted for application to a plant layout consisting of what may be termed a single "gas-generating unit" (i.e. compressor and compressor-driving turbine) and a single independent shaft-power turbine, is also applicable to other combinations of "generator units" and power turbines. For example, a plant according to the invention may comprise a single "gas-generating unit" (as above-defined) supplying working fluid to a pair of power turbines each of which, in the case of a road vehicle, may supply shaft power to driving wheels on only one side of the vehicle.

The present invention may be usefully applicable to gas turbine plant in general, of whatever order of power, and therefore it is not to be understood that the invention is necessarily limited to plant of relatively low power.

What we claim is:—

1. A gas turbine plant for the production of shaft power, comprising a centrifugal compressor having diffuser ducting comprising passages of variable throat area, combustion apparatus, a turbine system to drive the compressor and supply external shaft power, said system including at least one inward radial-flow turbine in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area, mechanism to vary the mass flow of the working fluid by modifying the turbine nozzle throat area and to effect conforming adjustment in the diffuser throat area, and fuel-control means to vary the quantity of fuel burnt in the combustion apparatus, the operation of the said mechanism and of the fuel-control means being so interdependent that a variation in mass flow effected by adjustment of the turbine nozzle area is associated with a corresponding variation in the quantity of fuel burnt.

2. A gas turbine plant according to claim 1, wherein the turbine system consists of a turbine which drives the compressor and also supplies external shaft power.

3. A gas turbine plant according to claim 1, wherein the turbine system consists of a turbine to drive the compressor, and a mechanically independent turbine to supply external shaft power.

4. A gas turbine plant according to claim 3, wherein the turbines are supplied with working fluid in series.

5. A gas turbine plant according to claim 4, wherein the compressor-driving turbine functions as the high-pressure turbine.

6. A gas turbine plant according to claim 4 or 5, wherein each turbine is of the inward radial-flow type in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area.

7. A gas turbine plant according to any preceding claim, wherein the or each variable nozzle means consists of a ring of vanes angularly adjustable in unison to vary the throat area of the nozzle passages they define.

8. A gas turbine plant according to any preceding claim, wherein the or each variable nozzle means consists of an adjustable vane adapted to throttle the entry to a volute delivering working fluid to the turbine rotor.

9. A gas turbine plant according to any preceding claim, wherein there is a mechanical connection between the fuel-control means and the mechanism for modifying the nozzle throat area of the turbine or turbines.

10. A gas turbine plant for the production of shaft power, comprising a centrifugal compressor having diffuser ducting comprising passages of variable throat area, heat input means, and a single turbine which drives the compressor and also supplies external shaft power, said turbine being of the inward radial-flow type in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area.

11. A gas turbine plant for the production of shaft power, comprising a centrifugal compressor having diffuser ducting comprising passages of variable throat area, heat input means, a turbine to drive the compressor, and a mechanically independent turbine to supply external shaft power, said turbines being fed with working fluid in series (either turbine being in the high pressure position) and each turbine being of the inward radial-flow type in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area.

12. A gas turbine plant for the production of shaft power, comprising a centrifugal compressor having diffuser ducting comprising passages of variable throat area, heat input means, a turbine to drive the compressor, and a mechanically independent turbine to supply external shaft power, said turbines being fed with working fluid in series and one turbine being an inward radial-flow turbine in which working fluid is continuously admitted to substantially the whole circumference of the rotor through nozzle means of variable throat area.

13. A gas turbine plant for the production of shaft power, substantially as hereinbefore described with reference to Figs. 1—9 and 11—12 and embodying the feature shown in Fig. 10.

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PROVISIONAL SPECIFICATION

Improvements relating to Gas Turbine Power Plant.

We, CENTRAX POWER UNITS LIMITED, a British Company of 87, High Street, Brentford, Middlesex, and RICHARD HENRY HOWARD BARR, a British Subject of the Company's address, do hereby declare the nature of this invention to be as follows:—

This invention relates to gas turbine power plants, and is concerned primarily with the provision of a combustion gas turbine power plant which is of relatively low power, in particular a plant for producing shaft power of an order of magnitude appropriate to road vehicles or small marine craft.

Reduction in the power output of open cycle gas turbines is most frequently achieved solely by reducing the fuel supply to the combustion means, with the result that low power outputs are accompanied by a substantial fall in the r.p.m. of the compressor, and in the maximum cycle temperature and pressure. Since the overall efficiency of such plants is dependent upon the maintenance of the cycle pressure and temperature as near as possible to their maximum values, it will be appreciated that at low power outputs the efficiency of the plant is very much impaired, the fuel consumption, though reduced, remaining at an uneconomically high level relative to the power produced. This drop in efficiency at part load, while acceptable in a power plant which usually functions under conditions approximating to full load, assumes a more serious character in the case of plants which during the greater part of their life are operating under low output conditions; such, for example, as the prime movers of road vehicles, which usually operate at near full throttle conditions for short periods only, and are running most of the time at low loads.

It is recognised that if the reduction in the fuel supply can be accompanied by an appropriate reduction in the mass flow of working fluid through the machine (additional, that is, to the reduction in mass flow which naturally results from throttling down the fuel supply), the optimum temperature and pressure would be more nearly maintained, resulting in better efficiency at fractional loads. One convenient known means of controlling mass flow in this way is to employ variable admission turbine nozzles, but, in the case of axial flow turbines, there is. so far as we know, no satisfactory means of varying the nozzle area without at the same time altering from its optimum

value the angle of incidence of the gas upon the turbine rotor blades, and thus introducing a loss in efficiency from this source.

The present invention has as a more specific object the provision of an open cycle gas turbine plant offering an improved performance at part load, and, from one view-point, is based upon a realisation that a turbine of the radial-vane centripetal flow type lends itself advantageously to variable nozzle control, since variation of the nozzle area does not appreciably affect the angle of incidence of the gas on the turbine vanes, at least not to an extent which results in any substantial loss of efficiency.

Control of power output by varying the mass flow, in addition to varying the fuel supply, implies, for satisfactory running over a wide range, the association with the turbine of compressor means which gives a satisfactory compression ratio over a wide range of mass flow variation, and which therefore should be substantially free from surging at low mass flows. In other words, the compressor or compressors should have a substantially flat pressure-ratio/mass flow characteristic for any given rotational speed.

The present invention therefore provides a gas turbine power plant including the combination of compressor means having a substantially flat pressure-ratio/mass-flow characteristic for any given rotational speed, and turbine means (preferably of the radial vaned centripetal flow type) having an arrangement (preferably variable admission nozzles) for controlling the mass flow of working fluid.

The expression "radial-vaned" is herein used to include cases in which the vanes are "backswept" or "forward-swept" from the truly radial direction.

A preferable form of compressor, as at present visualised, is a centrifugal compressor having a vaneless diffuser, which is found to give a pressure-ratio/mass-flow characteristic of the required form.

One species of power plant according to the invention includes the combination of a centrifugal compressor having a vaneless diffuser, and a compressor-driving turbine having variable admission nozzles.

A power plant according to the invention preferably includes at least one independent power turbine from which the shaft power is taken, and this independent turbine is preferably also of the radial-vaned centripetal flow type having variable nozzle control.

The use of a radial vane centripetal flow turbine involves other advantages additional to that of lending itself well to variable nozzle control. For instance, the turbine rotor, being of comparatively simple construction, embodying a small number of vanes, is simpler and cheaper to manufacture than an axial flow turbine rotor having a large number of blades each of which must be of exactly finished aerodynamic profile. Moreover, fewer nozzle vanes or the equivalent are required than for an axial flow turbine.

When, as will usually be the case, an independent power turbine is employed, a power unit according to the present invention is well adapted to provide compact space-saving constructions in which the power turbine is disposed other than co-axially with the compressor-driving turbine. This advantage arises from the fact that the gas outlet from the compressor-driving turbine is in the form of an annulus of small diameter which can conveniently be merged into a duct leading the working fluid in any direction adapted to a chosen location for the power turbine which, as expressed above, is preferably also a radial-vaned centripetal flow turbine.

One form of power plant according to the present invention will now be described in greater detail for the sake of example:—

This plant, which is particularly intended for road vehicle propulsion, comprises a centrifugal compressor having a vaneless diffuser space from which the compressed air is led through a heat exchanger, where it is preheated by extracting heat from the power turbine exhaust gases, and thence to a combustion chamber or chambers, where fuel is burnt. The resultant gases are fed to a radial-vane centripetal flow turbine (the rotor of which is on a common shaft with the compressor and comprises a disc member having on one face a number of radially extending vanes similar to those of the impeller of a centrifugal compressor) by way of a volute leading to a ring of nozzle vanes which are pivotally mounted for adjustment to vary the nozzle area. The gases enter the turbine rotor at the periphery and flow in a centripetal direction, emerging at the "eye" of the rotor, whence they enter a duct which leads the gases directly into the entry volute of a second radial vane centripetal flow turbine forming the power turbine, which also has adjustable nozzle vanes. The power turbine is mounted on a shaft at right-angles to, and lying in a different dimensional plane from, the common shaft of the compressor and its turbine. From the power turbine the gases pass to the hot side of the heat exchanger, whence they are exhausted to atmosphere.

A common means is provided to control the adjustment of the nozzle vanes of each turbine.

The fuel control means is preferably interconnected with the means controlling the turbine nozzle vanes, and operated by a single lever or pedal, the arrangement being such that variation in the fuel supply is automatically accompanied by an appropriate adjustment of the variable nozzles to vary the mass flow in the appropriate sense. The control of power output is brought about in part by variation of the mass flow control, and in part by the fall in maximum cycle temperature, pressure,

and compressor r.p.m. brought about by control of the fuel delivery, such fall being very much less than would be the case if the power output were controlled only by fuel feed adjustment.

Due to the speed range of the compressor being relatively small, it will be appreciated that when the power output control is fully opened the plant gives full power quickly, without the delay which, in a plant controlled only by fuel variation, results from having to motor up the compressor from a slow speed.

Yet another advantage is that the effort required to turn over the plant for starting is reduced, due to the lower mass flow at reduced settings of the power control.

The above-described form of plant may be conveniently arranged in a road vehicle chassis in such manner that the compressor/turbine shaft lies vertically, while the shaft of the power turbine extends in a fore and aft direction.

It will be appreciated that the present invention, in addition to being well adapted for application to a plant layout consisting of what may be termed a single " generating unit " (i.e. compressor and compressor-driving turbine) and a single independent shaft-power turbine, is also applicable to other combinations of " generator units " and power turbines. For example, a plant according to the invention may comprise a single " generating unit " (as above-defined) supplying working fluid to a pair of power turbines each of which, in the case of a road vehicle, may supply shaft power to driving wheels on only one side of the vehicle. The said pair of power turbines, if of the radial-vaned centripetal flow type, might conveniently be disposed back to back, and both be supplied with working fluid through one set of variable nozzles, such an arrangement might be so contrived as to give a differential effect, so that the retarding of one power turbine as the vehicle negotiates a corner would permit the working fluid to accelerate the other power turbine.

In an alternative type of layout, two power turbines might each be supplied with working fluid by one " generator unit."

As an alternative type of compressor it may be possible to use a centrifugal compressor with a vaned diffuser if means, such as pivoted vanes, is employed to vary the diffuser area. In such an arrangement it would be contrived that the diffuser area is diminished step-by-step with the reduction in fuel supply and the reduction in turbine nozzle area.

It is possible that the present invention may be usefully applicable to gas turbine plants in general, of whatever order of power, and therefore it is not to be understood that the invention is necessarily limited in usefulness to plants of relatively low power.

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701,557 COMPLETE SPECIFICATION
7 SHEETS
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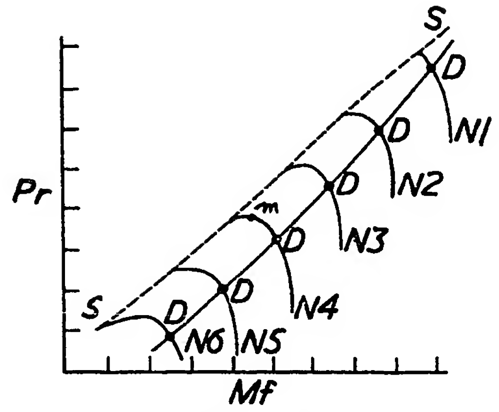

Fig. 1.

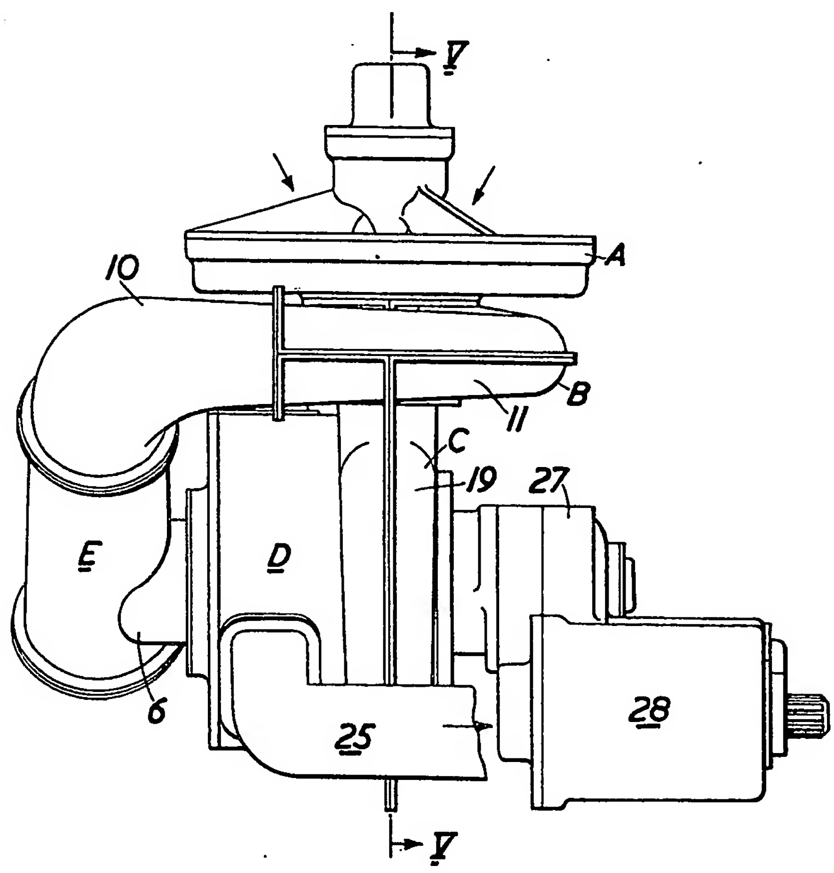

Fig. 2.

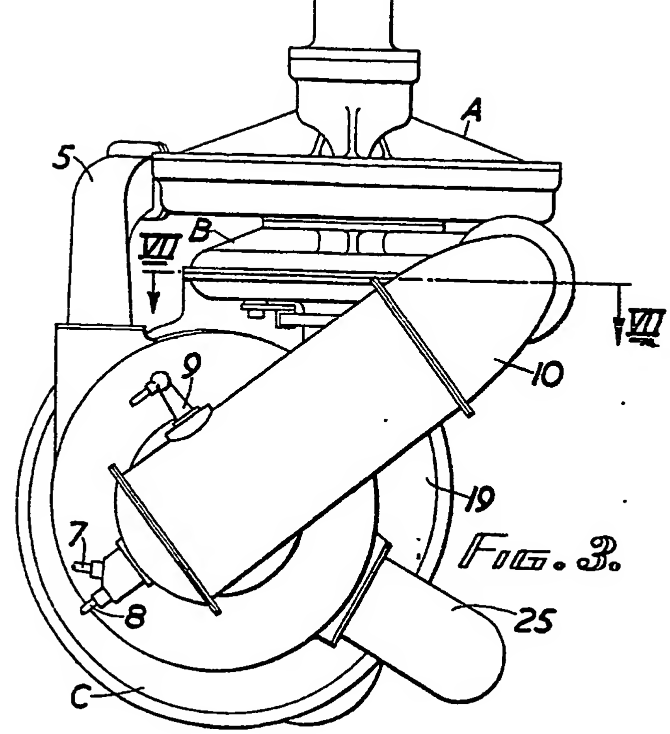
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FIG. 3.

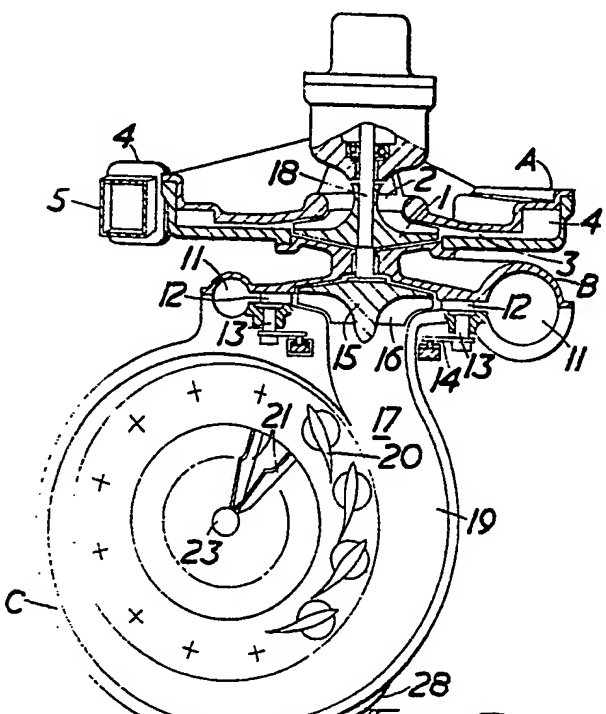
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FIG. 5.

701,557 COMPLETE SPECIFICATION
7 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 2 & 3

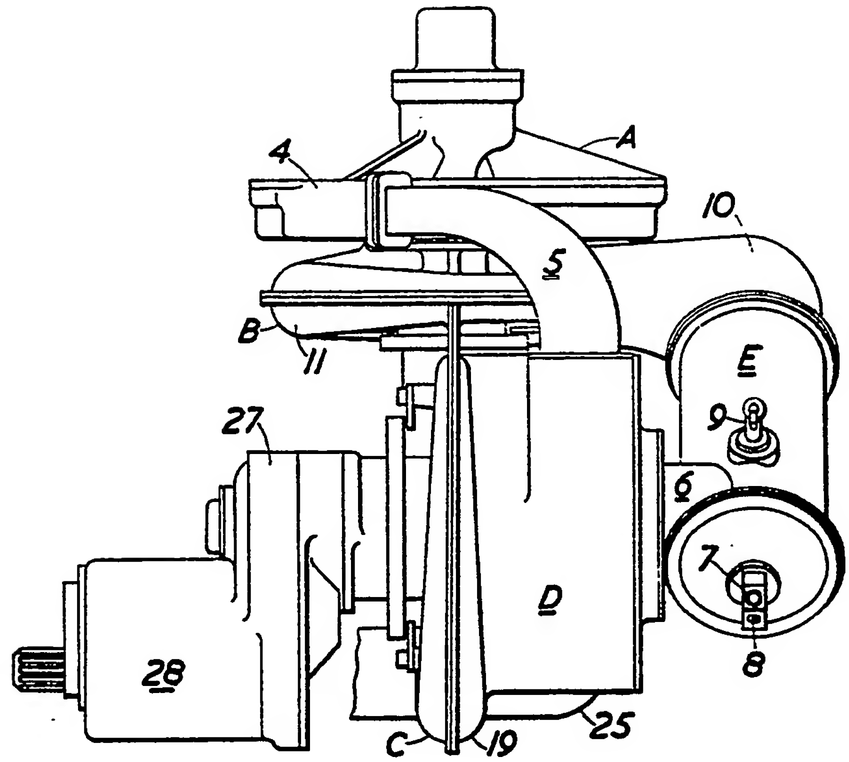


FIG. 4.

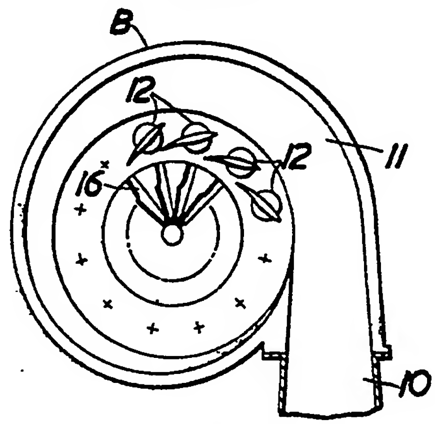


FIG. 7.

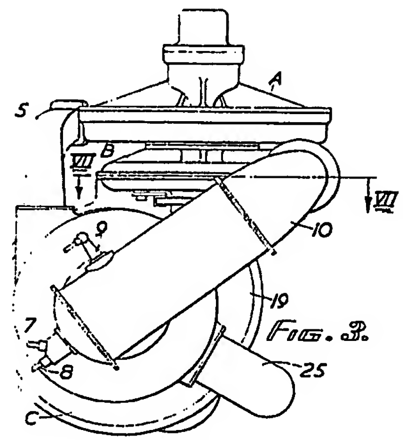


Fig. 3.

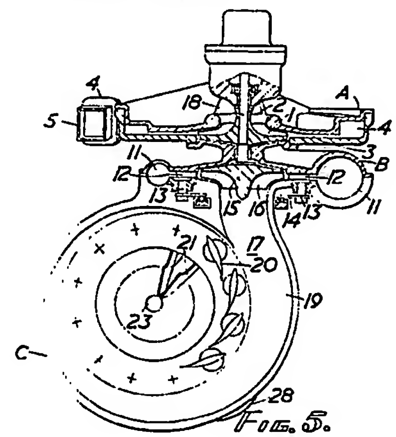


Fig. 5.

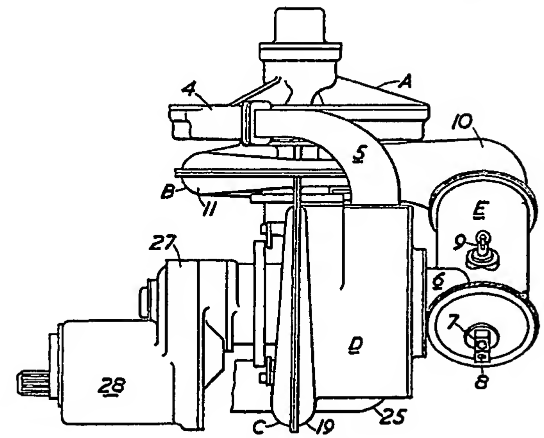
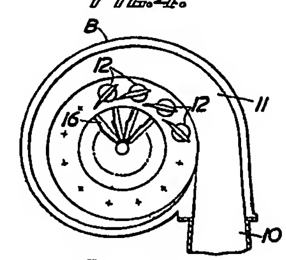


Fig. 4.



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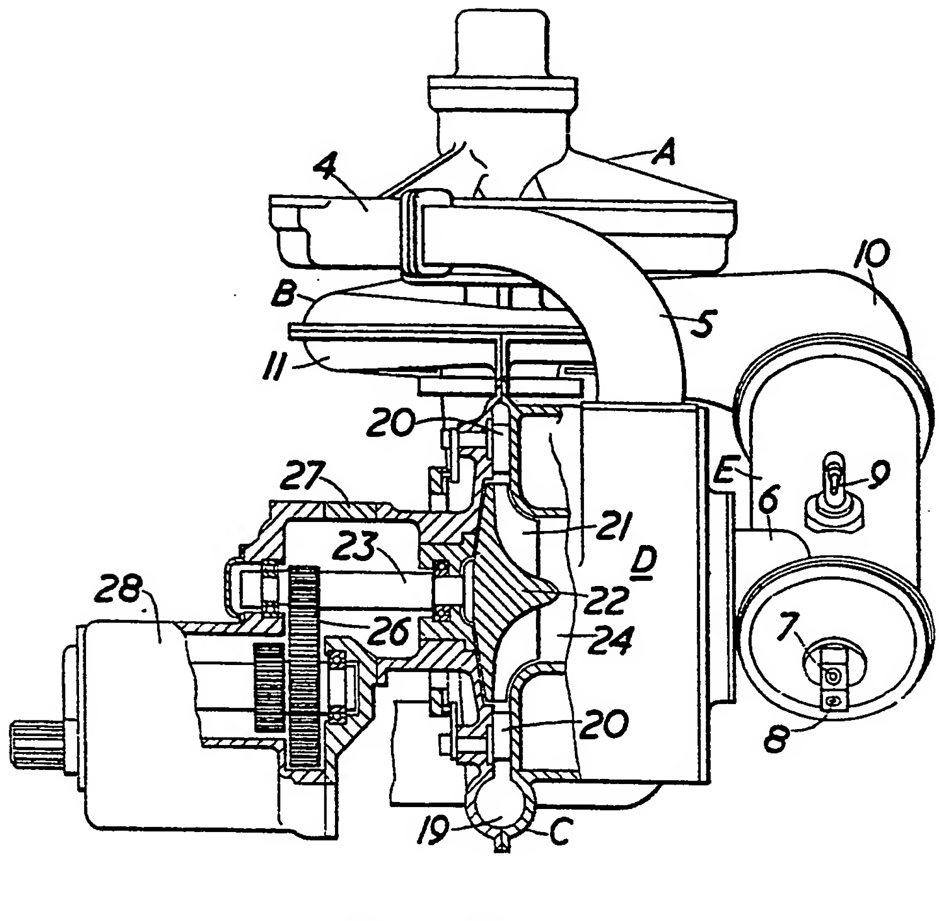
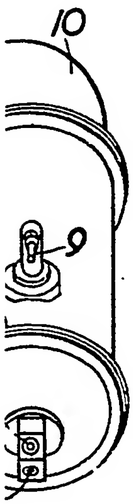


FIG. 6.

701,557 COMPLETE SPECIFICATION
7 SHEETS

This drawing is a reproduction of the Original on a reduced scale.

SHEETS 4 & 6



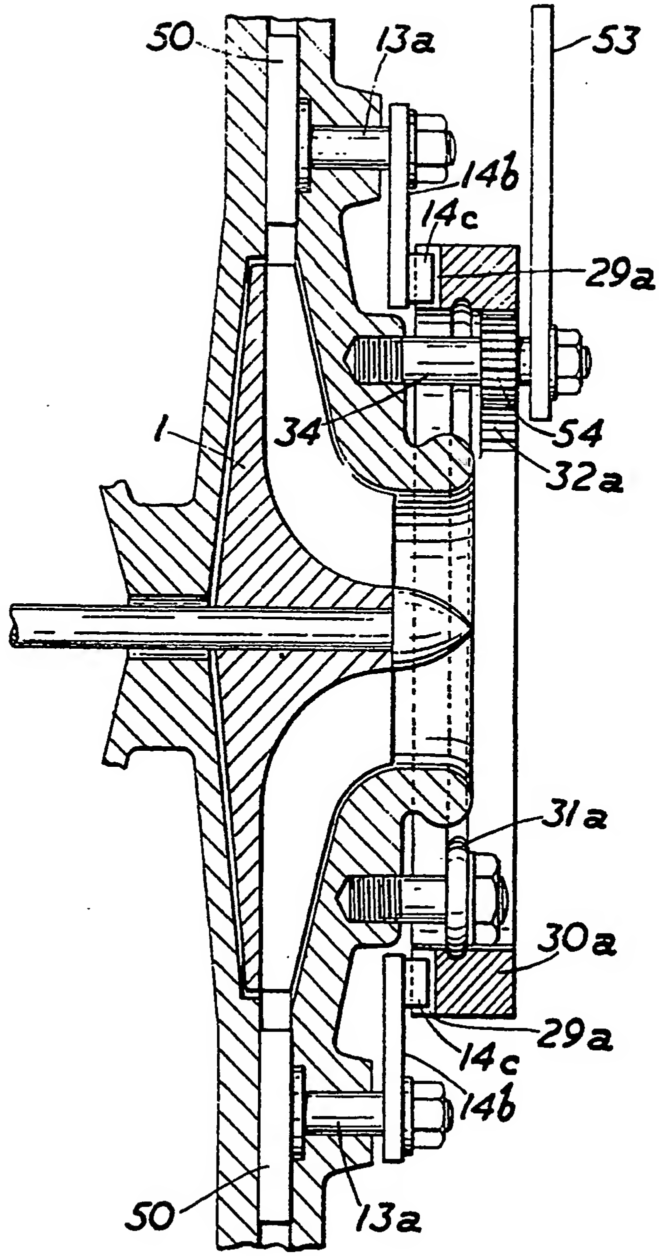
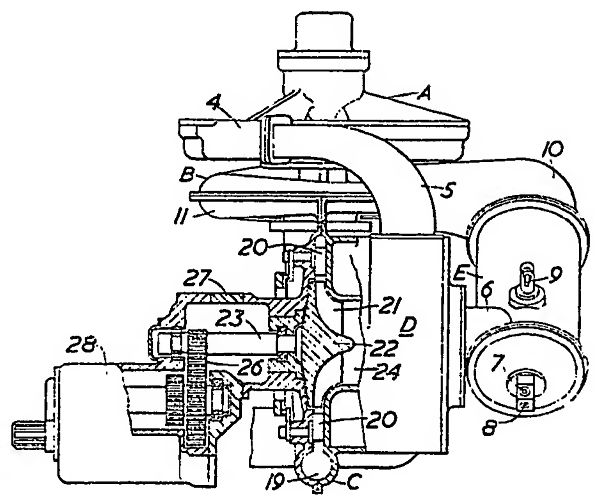
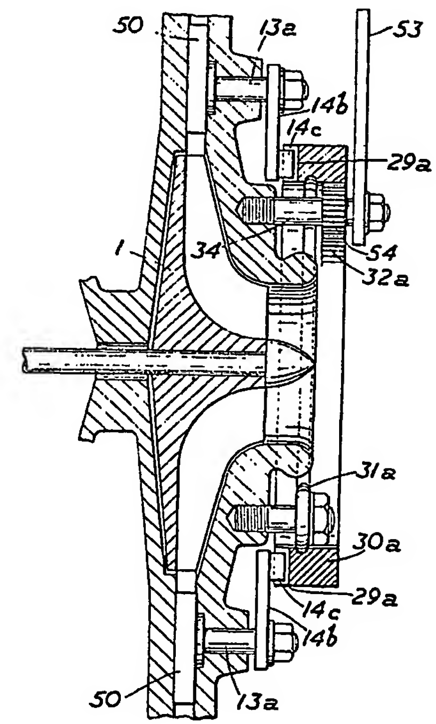


Fig. 10.


4
A
10
B
5
11
20
27
E
6
9
21
23
D
28
22
26
24
7
20
8
19
C
Fig. 6.


50
13a
53
14b
14c
29a
1
34
54
32a
31a
30a
29a
14c
14b
50
13a
Fig. 10.

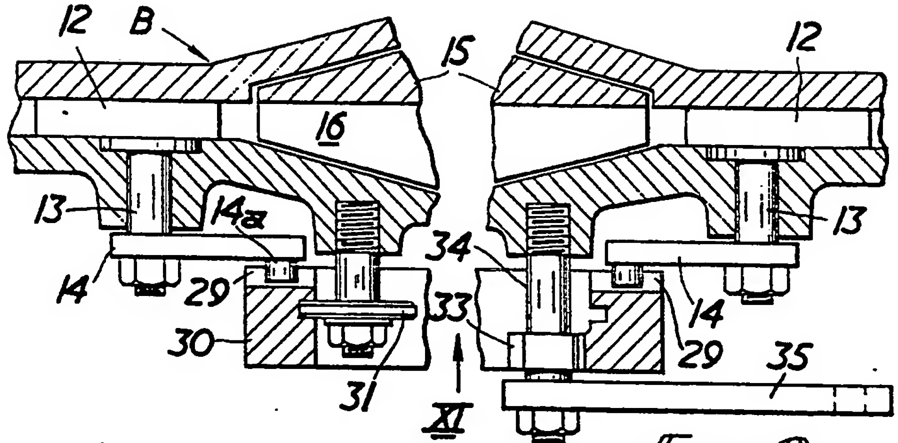


Fig. 8.

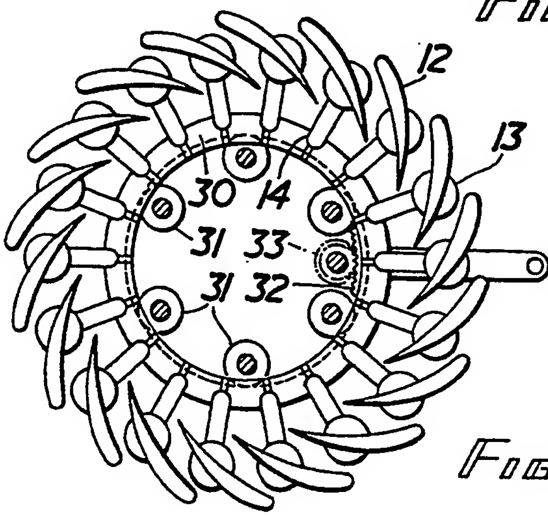


Fig. 9.

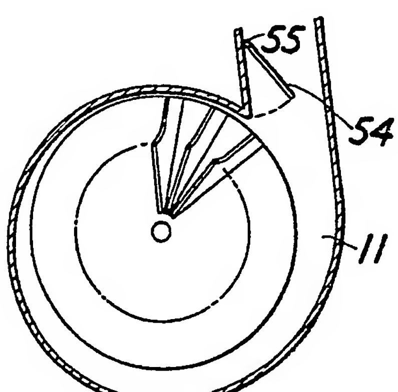
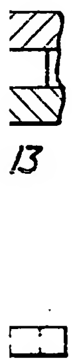


Fig. 12.

701,557 COMPLETE SPECIFICATION
7 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 5 & 7



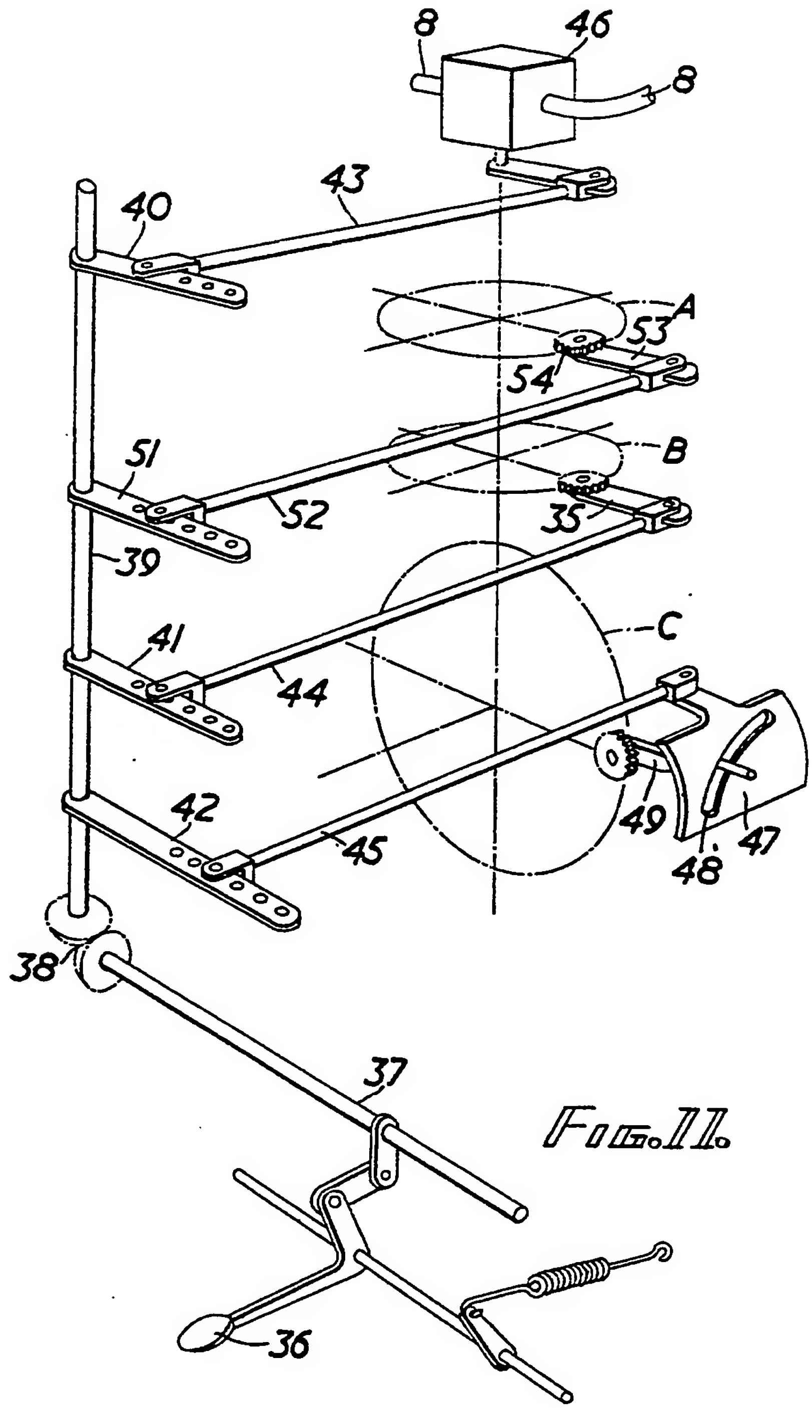


FIG. 11.

701,557 COMPLETE SPECIFICATION
7 SHEETS
This drawing is a reproduction of the Original on a reduced scale
SHEETS 5 & 7

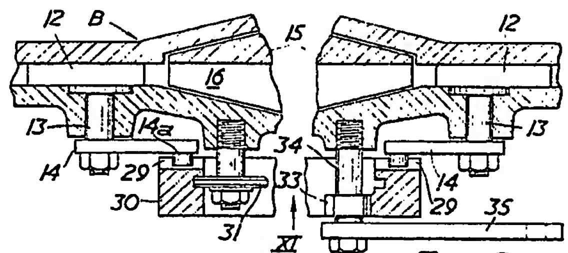


FIG. 8.

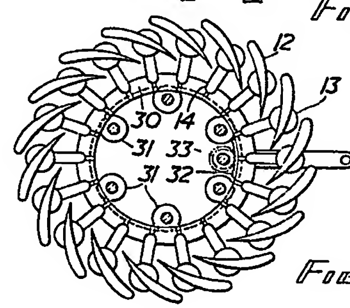


FIG. 9.

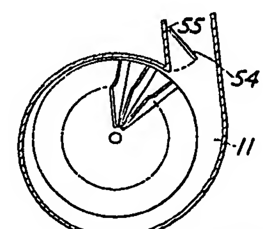


FIG. 12.

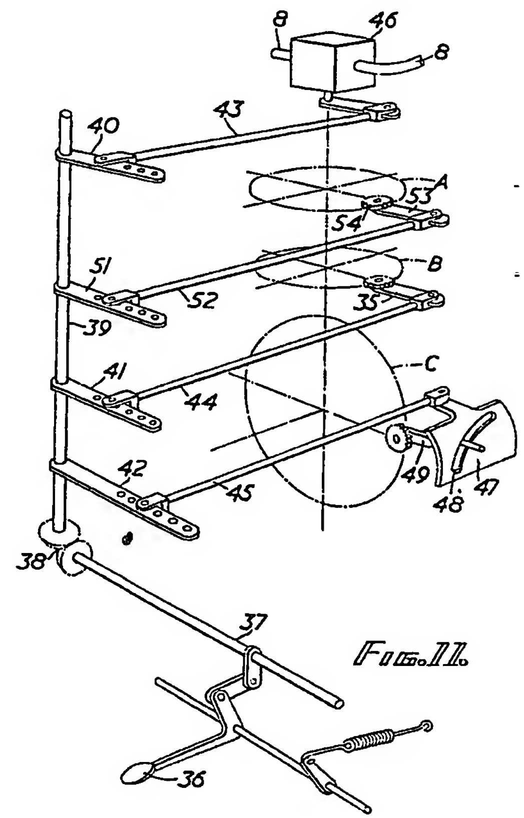


FIG. 11.